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Using Expert Opinion to Evaluate a Habitat Effectiveness Model for Elk in Western Oregon and Washington

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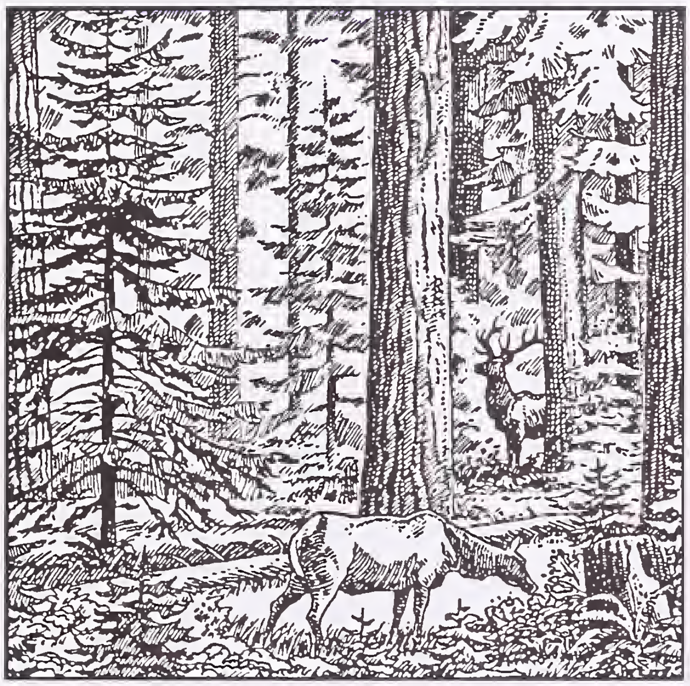

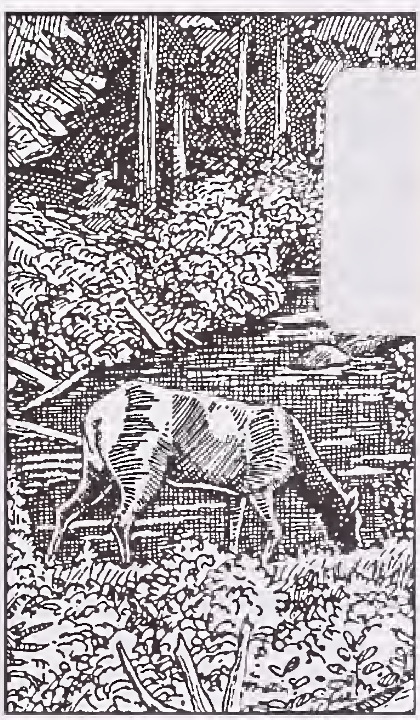

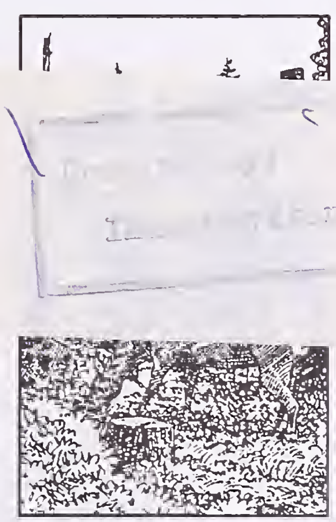

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Abstract

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We used expert opinion to evaluate the predictive reliability of a habitat effectiveness model for elk in western Oregon and Washington. Twenty-five experts in elk ecology were asked to rate habitat quality for 16 example landscapes. Rankings and ratings of 21 experts were significantly correlated with model output. Expert opinion and model predictions differed for 4 of the 16 landscapes. Differences were most pronounced for habitats dominated by large expanses of either forage or cover.

Keywords: Elk, elk habitat, habitat effectiveness, habitat models, elk management, model validation, Roosevelt elk, validation research, expert opinion, western Oregon, western Washington.

Summary

Habitat effectiveness models are widely used by natural resource agencies to predict effects of management activities, especially timber harvest, on elk habitat. We evaluated such a model for elk in western Oregon and Washington by using expert opinion. Experts in elk ecology rated habitat quality, on a scale of 0 to 1.0, for 16 example landscapes depicted on computer-generated maps. Landscapes represented the full range of habitat conditions likely to occur within subwatersheds in western Oregon and Washington. Model output was then generated for the same landscapes.

The rankings and ratings from 21 of the 25 experts were correlated ($P < 0.05$) with model predictions, suggesting close agreement between expert opinion and model output. Scores of experts and the model differed ($P < 0.05$) for 4 of the 16 landscapes, however. Differences were most pronounced for three maps that represented habitats dominated by large expanses of either forage or cover. We conclude that current model output is a reliable indicator of expert opinion except in subwatersheds where the cover:forage ratio is less than 20:80 or greater than 80:20. In these cases, we recommend using expert assessments of habitat effectiveness as a substitute for model output. We also recommend additional testing, using a field-based standard of comparison, to refine and validate the model.

Contents

Introduction

A variety of habitat models have been developed to predict how wildlife species respond to habitat change (for review, see Morrison and others 1992). How well these models perform depends on several factors: the validity of research data on which they are based, validity of the model structure, and adherence of model users to assumptions implicit in the models (Verner and others 1986).

Data used to develop models often are deficient, leaving model predictions biased or unreliable (Laymon and Barrett 1986). Bias can result from inadequate sample size, lack of replication, confounding variables, poor sampling design, or inappropriate methods (Verner and others 1986). Thus, model predictions should be validated by additional research designed to test and improve model reliability (Marcot and others 1983), often called validation research or validation monitoring (Schweitzer and MacNaughton 1990). Validation research is not always possible; time, budgets, or other resources often are limiting. Even when possible, it is rarely accomplished within an acceptable timeframe (Berry 1986). As an alternative, expert opinion may be used instead of validation research (Montopoli and Anderson 1991, Mulé 1982, O'Neil and others 1988, Schuster and others 1985). In this approach, predictions by experts are compared with those of the model to detect how similar they are. The higher the positive correlation, the better the model is assumed to predict a species' response to habitat change (O'Neil and others 1988).

We present results of expert opinion as a means to test the predictive reliability of a habitat effectiveness (HE) model for Roosevelt elk (*Cervus elaphus roosevelti* Merriam) in western Oregon and Washington (Wisdom and others 1986). Our objectives were to (1) determine how well model predictions matched those of experts; (2) identify differences, if any, between predictions of experts and those of the model under an array of habitat conditions; and (3) use results as a guide to modify model structure so that predictions better match those of experts. These objectives were based on feedback from model users, who expressed concern about the validity of model predictions for certain landscapes. Thus, we assumed that model output could be improved by incorporating the perceptions of experts, as done by O'Neil and others (1988).

Habitat Models: Concepts and Definitions

The most common models to predict wildlife response to habitat change evaluate habitat suitability (Berry 1986, U.S. Department of the Interior 1981). Habitat models for elk (Thomas and others 1988, Wisdom and others 1986) contain the same structure as, and provide outputs similar to, models of habitat suitability but are referred to as "models of habitat effectiveness" (Christensen and others 1993, Lyon and Christensen 1992). Models of habitat suitability or effectiveness generally index potential species or guild use of habitat patches within a subwatershed or at another appropriate scale. Predicted use is described as a relative probability distribution, which is the relative proportion of time or area that a habitat patch is used by a species or guild relative to optimum use (Marcot and others 1994). Probability distributions are scaled from 0.0 to 1.0, where 1.0 represents 100 percent probability of use by a species or guild relative to other habitat patches having probabilities less than 100 percent. Similarly, 0.0 is equal to 0 percent probability that a particular area is used (U.S. Department of the Interior 1981). The sum of all probabilities within a subwatershed, weighted by area, equals the composite, relative probability of species or guild use for the entire subwatershed (Marcot and others 1994).

Habitat effectiveness for elk is defined as the percent of area or percent of time that habitat is fully usable by elk during the nonhunting season (Lyon and Christensen 1992). Models of habitat effectiveness predict relative use by elk for an analysis area and for the composite of analysis areas within a subwatershed (Thomas and others 1988, Wisdom

and others 1986). Changes in habitat effectiveness for elk indicate trends in habitat quality, but not the degree of effect on population size.[1] Rather, habitat effectiveness models are simply a means for managers to set habitat goals, detect trends in habitat, and assess compliance in management of elk habitat (Christensen and others 1993; see footnote 1).

Habitat effectiveness models for elk are widely used by Federal land management agencies in the Pacific Northwest (see footnote 1). The models for elk have not been validated,[2] although applicable research is underway (Johnson and others 1991).[3] We assume that the use of expert opinion as presented here will guide model refinement until additional validation data are available.

Methods To Gather Expert Opinion

We designed 16 maps to represent the full range of variation in elk habitat that likely occurs within subwatersheds of western Oregon and Washington. Each map simulated a different array of forage areas (see appendix 2 for definitions of habitat terms), cover types, and road densities within the range of potential variation (fig. 1). All habitat was assumed to be either a forage area or one of the three cover types. We also summarized these data in tabular form (table 1) to complement the maps. Definitions used to map and summarize habitat characteristics followed those described in the HE model for elk in western Oregon (Wisdom and others 1986; appendix 2); the reader is referred to this publication for a detailed description of the model, its assumptions, and calculation of values.

Two sets of the 16 maps, each generated by a geographic information system (GIS), were available for experts during the assessment. One set of maps was generated at a scale of 1:24,000 and displayed on the walls of the room in which the assessment took place; the other set, generated at a smaller scale (1:42,000), was provided to each expert along with the tabular data. This allowed experts to view maps and tabular data clearly and efficiently during the entire process.

We identified 25 elk experts from western Oregon and Washington to participate in an assessment of these maps and tabular data. Experts were identified based on their experience, knowledge, and professional accomplishments in the management or research of Roosevelt elk. They represented a broad range of experience in management and research and of employers, including state, Federal, tribal, and private entities.

Before the assessment began, experts were asked to complete a questionnaire about their knowledge and experience in using or reading about the elk model by Wisdom and others (1986), and about their employers and work experience. This allowed us to account

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[1] Wisdom, Michael J.; Rowland, Mary M., comps. [In preparation]. Procedures for monitoring elk habitat and populations in National Forests of the Blue Mountains. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

[2] Rowland, Mary M.; Cook, John G. [In preparation]. Validation monitoring and research needs for elk in the Blue Mountains. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

[3] Cook, J.G.; Irwin, L.L.; Bryant, L.D. [and others]. 1994. Studies in elk biology in northeast Oregon: 1993 progress report. Unpublished progress report. [Corvallis, OR: National Council of the Paper Industry for Air and Stream Improvement]. On file with: NCASI, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850.

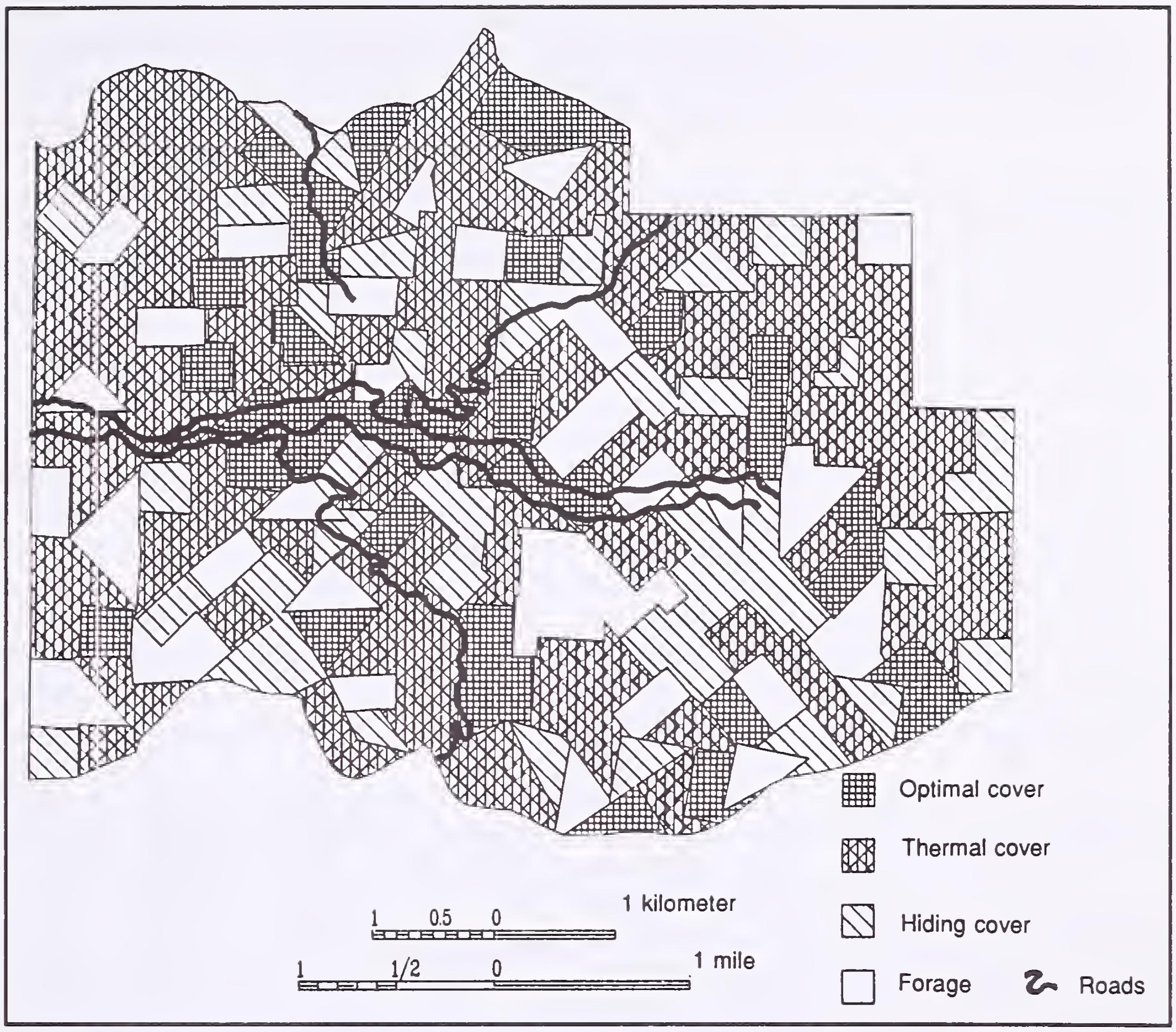

Figure 1—Example of landscape map (number 12) provided to experts for assessment of elk habitat effectiveness; each landscape encompasses 10,000 acres. Habitat types are defined in appendix 2.

for potential variation among expert assessments due to differences in employers, work experience, or familiarity with the model.

All the experts were given a set of written instructions and a summary of background assumptions, in addition to the maps and tables, to guide their assessments. Experts were instructed to rank the maps from highest (1) to lowest (16) habitat quality, and to rate each map for overall habitat effectiveness on a scale ranging from 0 to 100 percent. This scale was the same as that produced by model output (Wisdom and others 1986), thus facilitating statistical analysis of differences between expert and model predictions.

We asked experts to identify what habitat factors (for example, roads or cover; see appendix 1) had the most influence on their assessments, and to explain why. This allowed us to identify which habitat factors experts considered most important; it also provided additional background information to explain potential differences among expert assessments and between expert assessments and model predictions. Experts also were asked to identify which geographic area within western Oregon or western Washington they were basing their assessment on (appendix 1). This enabled us to test for differences in expert assessments by geographic area.

Table 1—Tabular data for habitat factors provided to experts with maps during assessment of elk habitat effectiveness of 16 sample landscapes in western Oregon and Washington[a]

Map	Forage area	Cover area: Hiding	Cover area: Thermal	Cover area: Optimal	Cover area: Total	Cover/forage edge	Road density
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Thousand feet*	*Mi/mi²*
1	10,000	0	0	0	0	0	1
2	8,100	0	0	1,900	1,900	74	2
3	3,900	0	0	6,100	6,100	140	4
4	5,600	4,400	0	0	4,400	122	6
5	2,000	2,013	5,987	0	8,000	78	4
6	2,000	2,013	0	5,987	8,000	78	0
7	2,000	4,100	3,900	0	8,000	79	6
8	3,900	4,200	0	1,900	6,100	124	2
9	2,000	1,906	2,094	4,000	8,000	80	1
10	900	1,100	8,000	0	9,100	39	2
11	1,000	2,000	7,000	0	9,000	39	2
12	1,700	1,700	5,000	1,000	8,300[b]	43	1
13	3,400	0	0	6,600	6,600	91	0
14	3,400	3,400	0	3,200	6,600	86	4
15	4,900	5,100	0	0	5,100	54	0
16	5,600	4,400	0	0	4,400	86	4

[a] Habitat factors are defined in appendix 2.
[b] Sum of the 3 cover types does not equal 8,300 acres; this transcription error was present in the original tabular data given to experts.

Background assumptions provided to experts included the following: (1) that each map encompasses a subwatershed of 10,000 acres containing year-round (both summer and winter range) habitat for elk; (2) that expert assessment is based on current habitat conditions shown on the maps, and not on potential future conditions, given present habitat conditions; (3) that elk populations are hunted, and hunted in the same manner across all 16 subwatersheds; (4) that all roads are open to motorized vehicles year-round, are surfaced, and are managed similarly; (5) that other habitat factors not shown on the maps, such as physiography, soils, geology, and forage quality, are constant across all 16 subwatersheds and thus do not affect the assessment; (6) that terrain, because it was not considered in the maps, could not be considered a factor in hiding animals; (7) that habitat types (that is, cover types and forage areas) are displayed and summarized for each map as either forage areas, hiding cover, thermal cover, or optimal cover, using structural definitions described for each type in Wisdom and others (1986); and (8) that assessment is based on personal knowledge and judgment of each expert, and not on the basis of any existing, formal habitat models.

Experts made their assessments by attending any one of three meetings held in western Oregon and Washington during June and July 1989. At each meeting, experts were allowed 90 minutes to complete their assessments. Each expert was asked not to visit

or talk with other experts during the process, but to judge the maps independently. We provided the same instructions, maps, data, and forms (appendix 1) to experts at all three meetings, and monitored the process to ensure that experts understood the materials and had adequate time to make assessments.

Methods To Compare Expert Opinion With Model Predictions

Model predictions of habitat effectiveness were generated for each of the 16 maps by using methods described by Wisdom and others (1986). Predictions included values for three habitat effectiveness variables: (1) sizing and spacing of forage and cover areas (HE_S), (2) density of roads open to motorized vehicles (HE_R), and (3) cover quality (HE_C). The fourth model variable, habitat effectiveness due to forage quality (HE_F), was not computed because of the complexity of graphically displaying the hundreds of possible combinations of forage treatments by area, for each map and across maps. We estimated that asking experts to evaluate forage conditions would have more than doubled the evaluation period and increased the likelihood of experts misinterpreting the instructions or the maps. This may have confounded the variation of interest (differences between the model and experts' predictions) with variation due to misinterpretations. Therefore, the forage variable was held constant at 0.50 (on a scale of 0.0 to 1.0) for all 16 maps. We assumed that a value of 0.50 for forage quality reflected average forage conditions for most subwatersheds, and thus was a realistic rating. This assumption seemed reasonable, based on our experience in many informal applications of the model and on results of more formal application tests across multiple landscapes in western Oregon (Adams 1986).

An overall rating of habitat effectiveness (HE_{SRCF}) for each map was calculated as the geometric mean of the four HE variables (Wisdom and others 1986). These habitat ratings were used to rank the maps from highest (1) to lowest (16) habitat quality.

The 16 maps were ranked independently by each expert from highest to lowest habitat quality, based on the maps themselves and data provided in table 1. Experts were then directed to rate each map, in terms of overall habitat effectiveness, from 0.0 to 1.0, assuming that forage quality was constant across all maps.

We tested the null hypotheses that there was (1) no correlation ($\rho = 0$) and (2) no difference ($HE_{experts} - HE_{model} = 0$) between expert opinion and model predictions through the following analyses. Samples were assumed to be randomly obtained from a bivariate normal distribution, and observations were assumed to be independent. We considered probabilities (P) less than 0.05 significant.

For each expert, we tested for correlation between map and model rankings by using Spearman's coefficient of rank correlation (Sokal and Rohlf 1969, p. 538–540). Nonparametric tests for association are required when variables are measured on an ordinal scale, such as the relative rankings presented here. Likewise, for each expert, we used the parametric test of correlation analysis (Pearson's product-moment correlation coefficient [Sokal and Rohlf 1969, p. 508–515]) to test for association between map and model ratings of HE. Thus, we had 25 tests each for rankings and ratings.

We also calculated Pearson's correlation coefficient for the mean of all experts' ratings for each map and the model HE_{SRCF} score for the corresponding map. This provided a single r value to measure agreement of experts' ratings with model output.

For each map, we examined differences between the mean rating of habitat effectiveness by all experts and the value predicted by the model, using a one-sample t-test (Zar 1974,

p. 86–90). By using the one-sample t-test, we assumed that model predictions represented the ideal population, and that expert predictions represented samples that could be tested for statistical deviation from the ideal. Although the model represented the ideal population in a statistical sense, this did not imply that model predictions represented the most correct biological predictions. On the contrary, our objectives (see "Introduction") assumed that expert predictions were biologically more correct than the model's. The one-sample t-test was simply a statistically appropriate way to detect such differences.

We used the univariate one-sample t-test instead of the multivariate one-sample Hotelling's T^2 (Hair and others 1992) to intentionally increase the probability of type I errors, thus maximizing detection of potential differences between expert and model predictions. We then could identify all possible modifications needed in model structure to achieve better agreement with expert predictions. By increasing the probability of type I errors, we decreased the probability of type II errors that can result from small sample sizes (such as $n = 25$ in our case). Thus, we likely increased our power in regard to protection against type II errors, but decreased it for type I errors (Sokal and Rohlf 1969). This allowed us to view any findings of no statistical difference between expert and model predictions as compelling evidence that no modifications in model structure were needed for maps in which $P > 0.05$, a situation we viewed as desirable considering our small sample size and the likelihood of otherwise committing type II errors.

Experts attended one of three meetings to participate in the evaluations, and chose one of four geographic areas that best matched the locale of their experience in judging elk habitats. To determine if we could combine data for analysis from these geographic areas, and from the three dates, we tested for differences among ratings by area and date using one-way analysis of variance (Zar 1974, p.133–139). We also examined responses of experts to the questionnaire to determine how many experts had used the model regularly.

Finally, we were interested in delineating which habitat factors, if any, were statistically correlated with experts' ratings for maps. Thus, we calculated a separate correlation coefficient for each expert's ratings for the maps against the values presented for the habitat factors (table 1). We performed a similar correlation analysis of the individual model variables (HE_S, HE_R, and HE_C) with each expert's ratings.

Results

Twenty-four of 25 experts (96 percent) responded that they either had not used the model or had used it infrequently. This indicated that most or all expert assessments were likely independent of model predictions, an assumption implicit in our use of expert opinion as a means of model evaluation. These results also indicated that formal tests of correlation between expert familiarity with the model and their assessment of habitat quality were not needed.

Experts' ratings of HE differed by meeting date ($P < 0.05$) for only three maps, and by geographic area for only one map. Therefore, data collected from different meetings and geographic areas were combined for the final analysis; we also concluded that further analysis or refinement of the model based on differences in expert opinion by geographic area were not warranted.

Model ratings of overall habitat effectiveness for the 16 landscapes ranged from 0.165 (map 1) to 0.813 (map 13) (table 2). Experts' ratings had a very similar range, from 0.212 to 0.829; their highest and lowest ranking maps were the same as those ranked by the model (table 3). Map 13, the highest-ranked landscape, had no roads, a cover:forage

Table 2—Values calculated from an elk habitat effectiveness model[a] for individual model variables and overall index of habitat effectiveness for each of 16 sample landscapes in western Oregon and Washington[b]

Map	HE_S[c]	HE_C[d]	HE_R[e]	HE_{SRCF}[f]
1	0.050	0.050	0.600	0.165
2	.571	1.000	.500	.615
3	.952	1.000	.300	.615
4	.844	.100	.100	.255
5	.826	.402	.300	.472
6	.826	.780	1.000	.753
7	.911	.297	.100	.341
8	.934	.378	.500	.545
9	.828	.654	.600	.635
10	.685	.455	.500	.528
11	.651	.412	.500	.509
12	.546	.608	.600	.562
13	.872	1.000	1.000	.813
14	.871	.532	.300	.514
15	.655	.100	1.000	.425
16	.720	.100	.300	.322

[a] Wisdom and others 1986.
[b] Habitat effectiveness due to forage quality (HE_F) fixed at 0.50 for all maps.
[c] Habitat effectiveness due to sizing and spacing of cover and forage areas.
[d] Habitat effectiveness due to cover quality.
[e] Habitat effectiveness due to road density.
[f] Overall habitat effectiveness index.

ratio near 60:40, and only optimal cover (that is, no hiding or thermal cover present). In contrast, map 1 was the only one with no cover at all. For individual variables of the model, ratings ranged from 0.050 to 0.952 for sizing and spacing (HE_S), from 0.050 to 1.000 for cover quality (HE_C), and from 0.100 to 1.000 for road density (HE_R).

Means of the experts' ratings for landscapes generally were not different than model predictions (table 3). Overall ratings and rankings of the 16 landscapes were correlated ($P < 0.05$) with model predictions for 21 of 25 experts (fig. 2). Correlation of the mean of all experts' ratings for each map with the model score also was significant ($r = 0.91$, $P < 0.0001$).

This general agreement between experts and the model provided rationale for examining which individual landscapes were the source of the greatest discrepancies, if any, between expert opinion and model predictions. One-sample *t*-tests of differences between the mean of experts' ratings and model output for each map were based on the null hypothesis that expert opinion was no different than model scores. This hypothesis was rejected for only four landscapes, but landscape 9 also was very close to the rejection level of $P = 0.05$ (table 3). Differences were especially marked for landscapes 2, 10, and 11; moreover, the greatest discrepancies between rankings of the experts versus those of the model were for landscapes 2 and 10 (table 3).

Correlation analysis suggested that, of the seven habitat factors for which data were provided to experts (table 1), amount of optimal cover was most often associated with

Table 3—Comparison of model predictions of habitat effectiveness for elk with experts' ratings, for 16 sample landscapes in western Oregon and Washington

	Ranking[a]		HE[b]		
Map	Model	Experts	Model	Experts[c]	P[d]
1	16	16	0.165	0.212 (0.185)	0.268
2	4.5	10	.615	.398 (.194)	<.0001
3	4.5	5	.615	.594 (.217)	.709
4	15	15	.255	.253 (.175)	.927
5	11	8	.472	.454 (.161)	.632
6	2	2	.753	.749 (.180)	.982
7	13	13	.341	.334 (.157)	.840
8	7	4	.545	.624 (.198)	.044
9	3	3	.635	.701 (.174)	.051
10	8	12	.528	.384 (.162)	.0001
11	10	11	.509	.390 (.191)	.004
12	6	6	.562	.580 (.180)	.576
13	1	1	.813	.829 (.177)	.593
14	9	7	.514	.539 (.201)	.482
15	12	9	.425	.436 (.186)	.869
16	14	14	.322	.326 (.180)	.435

[a] Maps ranked from highest (1) to lowest (16); model rankings based on HE ratings.
[b] Overall habitat effectiveness; possible range of 0.0 to 1.0.
[c] Mean (standard deviation); n = 25.
[d] Results of one-sample t-test of model versus experts' HE ratings; $P < 0.05$ considered significant.

experts' HE scores ($P < 0.05$ for 22 of 25 experts; fig. 3). In contrast, amounts of hiding and thermal cover had the weakest association with expert opinion (fig. 3). Acres of total cover and forage, along with road density, were moderately associated with experts' HE ratings (significant correlation for 11 of 25 experts). The influence of optimal cover on experts' scores also was reflected in the correlation between values of HE_C generated by the model and habitat effectiveness ratings for 17 of the 25 experts (fig. 3).

Discussion

The model we evaluated (Wisdom and others 1986) was developed from a combination of both empirical data and expert opinion. At the time of its development, some testing was done to determine if it was a reasonable representation of the opinions of its developers. That work represented verification of the model formulation. Testing presented here, which relies on opinions from an independent set of experts, represents an evaluation of the model based on expert opinion for a full range of possible landscapes. The results demonstrate how well model predictions are correlated with expert opinion but not whether the model is a reliable predictor of elk habitat quality. Additional research is needed to answer the second question. The overall correlation of 0.91 for experts' mean ratings with the model output was especially noteworthy. O'Neil and others (1988), in using expert opinion to modify a HE model, obtained an r value of 0.82 only after four revisions of their model for hairy woodpeckers (*Picoides villosus*).

Our results indicated that model predictions are a reliable indicator of expert opinion over a broad range of landscapes. Expert ratings and rankings were correlated ($P < 0.05$) with

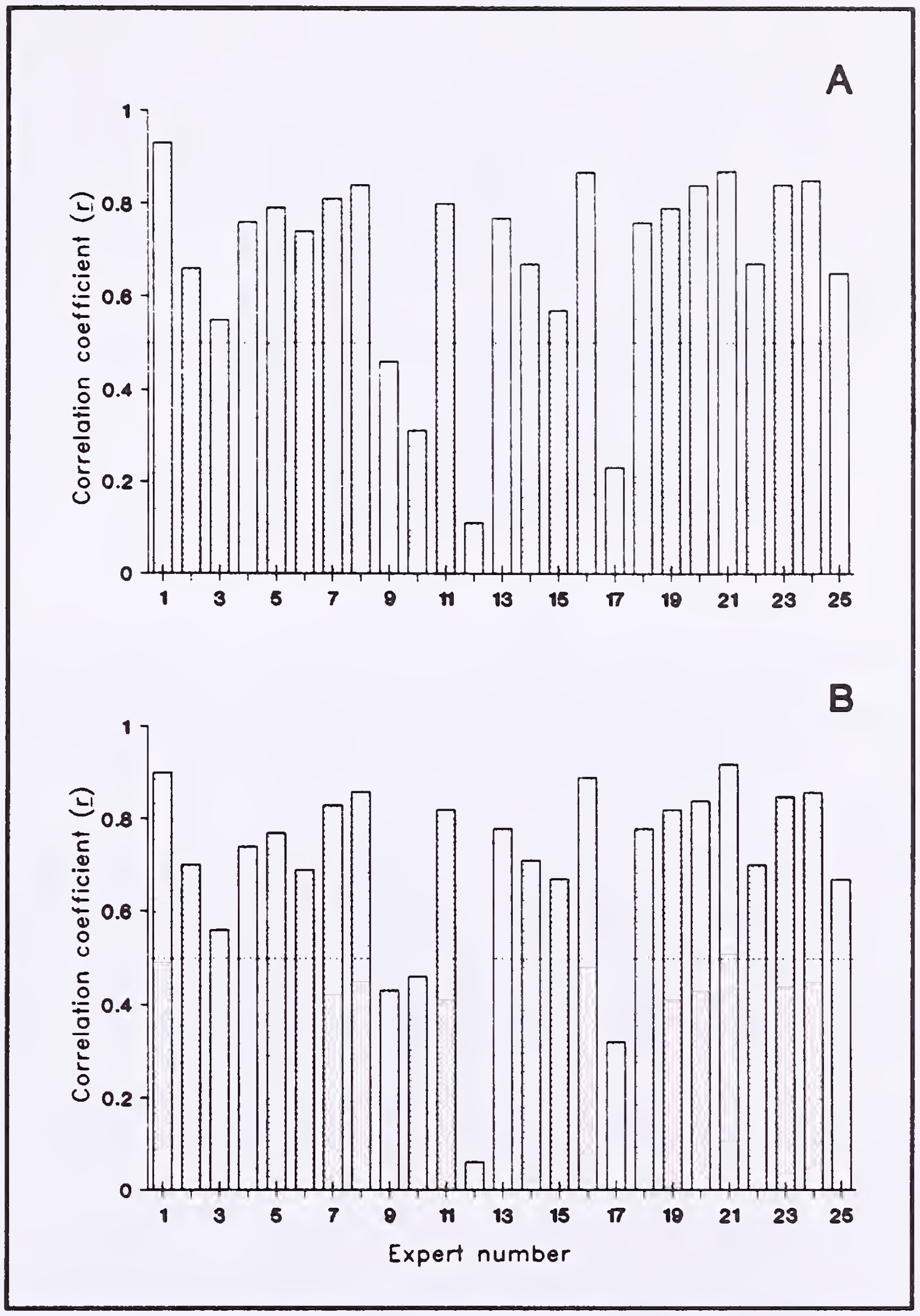

Figure 2—Correlation of model versus expert rankings (2A; Spearman's correlation coefficient, with d.f. = 16) and ratings (2B; Pearson's correlation coefficient, with d.f. = 14) of elk habitat effectiveness on 16 sample landscape maps; values of *r* above the dashed lines are significant at $P < 0.05$.

model output for 21 of 25 experts. On a landscape basis, our null hypothesis that the mean of expert ratings was no different than model predictions was rejected for only four landscapes. Because our power was likely high for protection against type II errors under the one-sample *t*-test (see "Methods to compare expert opinion with model predictions"), our finding of no statistical difference between expert and model predictions for the majority of landscapes further verified the high correlation between model and expert predictions.

Differences between experts and the model were greatest for landscapes 2, 10, and 11. Ratings from experts were significantly lower than those of the model for these landscapes, which contained a substantial amount of their total areas (greater than 80 percent) as either forage or cover. The only other test landscape similarly skewed was

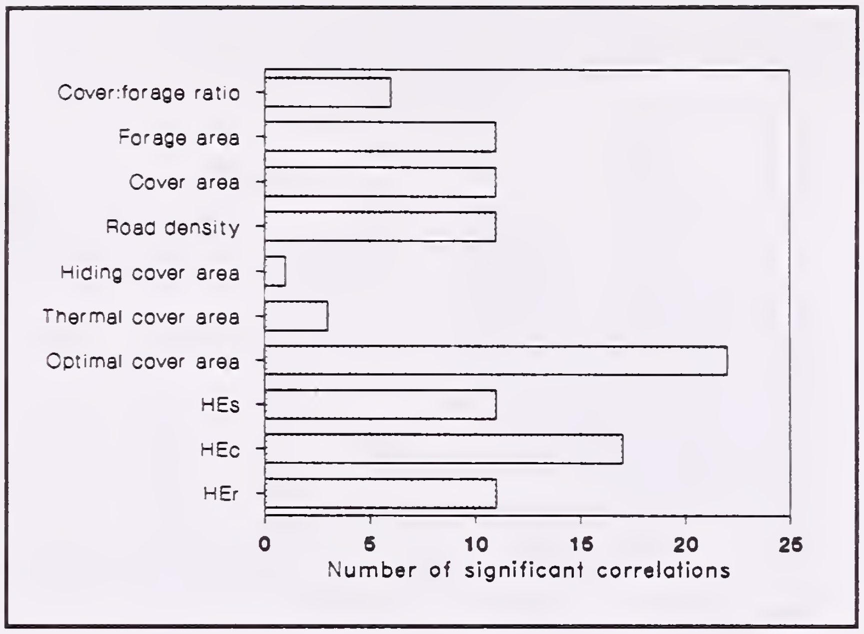

Figure 3—Degree of association of habitat factors and elk model variables with ratings of habitat effectiveness for elk by 25 experts, using Pearson's correlation coefficient; $P < 0.05$ is considered significant. Model variables are habitat effectiveness due to sizing and spacing of cover and forage areas (HE_S), due to cover quality (HE_C), and due to road density (HE_R).

landscape 12. Explanations given by the experts for their ratings of landscapes 2, 10, and 11 indicated that the cover:forage ratio of these landscapes was a major influence in their lower ratings of habitat effectiveness versus values predicted by the model. Differences between expert and model ratings of these landscapes were likely influenced by the relative insensitivity of the HE_S variable to different amounts of forage, and thus to cover:forage ratios (fig. 4). Instead, HE_S is sensitive to the patchiness of forage and cover areas and the percentages of these areas in various distance bands (Wisdom and others 1986). (Distance bands are 100-yard-wide bands away from cover-forage edges).

In contrast, comments from experts indicated that their opinions were sensitive to the percentage of area in forage, particularly when that percentage was greater than or equal to 80 percent, or less than or equal to 20 percent. This discrepancy between expert opinion and model prediction over the HE_S relationship likely explains a major part of the overall discrepancy observed between experts and the model for landscapes 2, 10, and 11.

Optimal cover was consistently viewed by experts as an important habitat characteristic (fig. 3). It also represented a key source of division for those whose opinions agreed with model output and those whose did not. The three experts whose scores did not correlate with amount of optimal cover also were three of the four whose overall opinions did not match the model (figs. 2 and 3). Other habitat factors, such as roads and total forage acreage, were strongly associated with these experts' scores.

Conclusions

Habitat effectiveness predicted by the model agreed closely with expert opinion except when landscapes contained more than 80 percent of the area in either forage or cover. Model predictions of habitat effectiveness were higher than those of the experts in those cases. The insensitivity of HE_S to extreme values for forage and cover may be responsible for this difference, as may be the model's structure. The use of the geometric mean in combining scores for individual model variables allows partial compensation for low scores of one variable with higher scores for other variables.

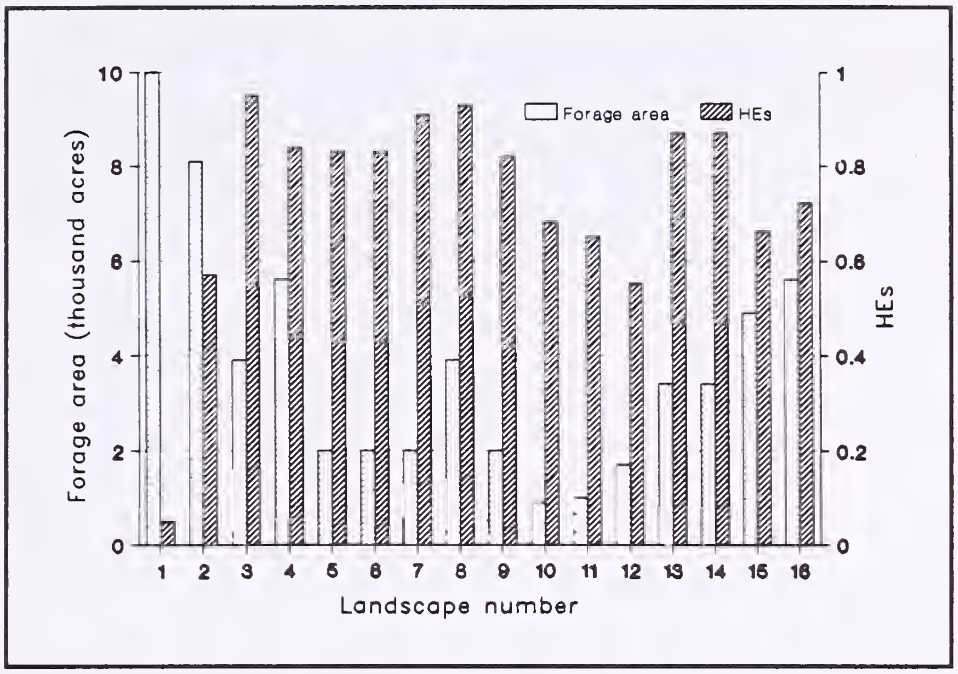

Figure 4—Relation between size of forage area and the model variable, habitat effectiveness due to sizing and spacing of cover and forage areas (HE_S).

We recommend that model structure be modified to better match expert opinion when cover:forage ratios are less than 20:80 or greater than 80:20. Specifically, we recommend that these values be set as thresholds. When such thresholds are exceeded, overall habitat effectiveness (HE_{SRCF}) should be lowered to 0.4. This value approximates expert opinion (based on results from maps 2, 10, and 11; table 3). If, however, HE_{SRCF} predicted by the model is less than 0.4 in these cases, we recommend that model predictions be used in unmodified form (see results for map 1; table 3).

These recommendations should be taken cautiously owing to the small sample size on which they are based. These recommendations do contradict results from map 12, where cover:forage ratios were greater than 80:20, but the model and experts agreed with a HE value of about 0.57 (table 3). The low road density for this landscape may have been responsible for this agreement. Until validation research of all model variables and their interactions is undertaken, however, these recommendations appear reasonable for most cases. They are based on the assumption that expert opinion can serve as an interim guide for modifying model output when the two methods differ.

We also recommend that model users calculate HE_F based on field records of forage treatments, rather than holding this value constant at 0.50. We held this variable constant only because of the difficulties in displaying the myriad of treatment combinations to the experts. This does not imply that HE_F is unimportant or should be held constant during actual evaluations of HE.

Differences between experts' and the model's sensitivity to cover:forage relations can be established from several different paths of inference, including (1) examination of the statistical differences in ratings for maps 2, 10, and 11; (2) the apparent differences in ranking of maps 2 and 10; and (3) experts' statements about factors that influenced their judgment of the three maps. The inference would have been much weaker if it had been based solely on ratings. Ratings imply some calibration of the model to absolute values of habitat effectiveness, but such calibration is problematic. The correlation established

in this study between model and expert ratings (fig. 2B) may have been influenced by the decision to have HE_F equal 0.50. A different value for HE_F, or holding a different variable constant, could have significantly altered this correlation. Thus, conclusions that can be based on rankings are likely less biased than those based on ratings. Interpretation of model results will be more valid if ratings are viewed as relative rather than absolute. Also, statistically significant differences between ratings of experts and the model do not necessarily imply that biological differences exist.

This work, and previous work by Montopoli and Anderson (1991) and O'Neil and others (1988), demonstrate the usefulness of professional opinion to validate habitat models. This procedure may be especially effective when models are controversial and model users question a model's utility. During our study, many of the experts became more comfortable with the model after participating in a structured comparison of their opinion with model results. These experts may influence the opinions of many other potential model users. This work also has provided a useful basis for making relatively minor modifications to the model.

Despite the usefulness of expert opinion, it should not be considered a substitute for validation based on field research. Expert opinion used to evaluate the model may not be any more robust than the opinion used to create the model, and may contain significant biases. Validation based on field research must be used to detect biases. Such research may not be completed, or even started, in the near future, however. Evaluation by expert opinion serves as a useful interim step for those obligated to conduct habitat assessments using HE models before full validation can be completed.

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Appendix 1: Rating Form

Form used by experts in rating example landscapes.

ELK HABITAT EVALUATION WORKSHEET

Worksheet Number

Date

Circle Geographic Area:

WA Coast/Olympics
WA Cascades
OR Coast
OR Cascades

Map #	Rank (1-16)	Rating (1-100)	Which Factor(s) Most Influenced Your Rating? 1) forage 2) cover 3) edge 4)roads 5) other factors (specify)	Explain Why / Other Comments

Appendix 2: Definitions

Habitat terms used by experts in evaluations of habitat effectiveness.

Cover/forage edge: the linear distance of the boundaries where forage and cover areas abut.

Forage areas: vegetated areas with less than 60 percent combined canopy closure of trees and tall shrubs (only trees and shrubs over 7 feet in height are considered in this definition).

Hiding cover: any vegetation capable of hiding a standing adult deer or elk at 200 feet or less—generally all stands in western Oregon and Washington not qualifying as forage areas or optimal or thermal cover.

Optimal cover: forest stands with dominant trees averaging 21 inches in diameter at breast height (d.b.h.) or larger, 70 percent crown closure or higher, and in the large sawtimber or old-growth stand condition.

Road density: number of miles of road per square mile of habitat; for this exercise, roads are assumed to be surfaced, managed similarly, and open to motorized vehicles year-round.

Thermal cover: stands at least 40 feet in height with tree crown closure of at least 70 percent—generally achieved in closed sapling/pole stands or older stands not qualifying as optimal cover.

Holthausen, Richard S.; Wisdom, Michael J.; Pierce, John; Edwards, Daniel K.; Rowland, Mary M. 1994. Using expert opinion to evaluate a habitat effectiveness model for elk in western Oregon and Washington. Res. Pap. PNW-RP-479. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p.

We used expert opinion to evaluate the predictive reliability of a habitat effectiveness model for elk in western Oregon and Washington. Twenty-five experts in elk ecology were asked to rate habitat quality for 16 example landscapes. Rankings and ratings of 21 experts were significantly correlated with model output. Expert opinion and model predictions differed for 4 of the 16 landscapes. Differences were most pronounced for habitats dominated by large expanses of either forage or cover.

Keywords: Elk, elk habitat, habitat effectiveness, habitat models, elk management, model validation, Roosevelt elk, validation research, expert opinion, western Oregon, western Washington.

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